

Chromaticity Measurement via RF Phase Modulation



classical measurement via RF frequency variation:

- requires detuning of the RF cavity



slow measurement ($f < 1\text{Hz}$)



RF phase modulation:

- allows fast RF adjustments $\longrightarrow > 100\text{Hz}$

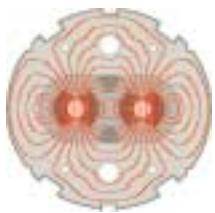
- small energy variation for fast phase modulation

- slow phase modulation can interfere with RF phase loop

$\longrightarrow f \approx 5 \text{ fs}$

$\xrightarrow{\text{(SPS)}}$

$f \approx 700\text{Hz} <\rightarrow 800\text{Hz}$



Chromaticity Measurement via RF Phase Modulation

- **energy modulation:** (Trevor Linnecar)

- RF phase modulation of 3 degrees (LHC)

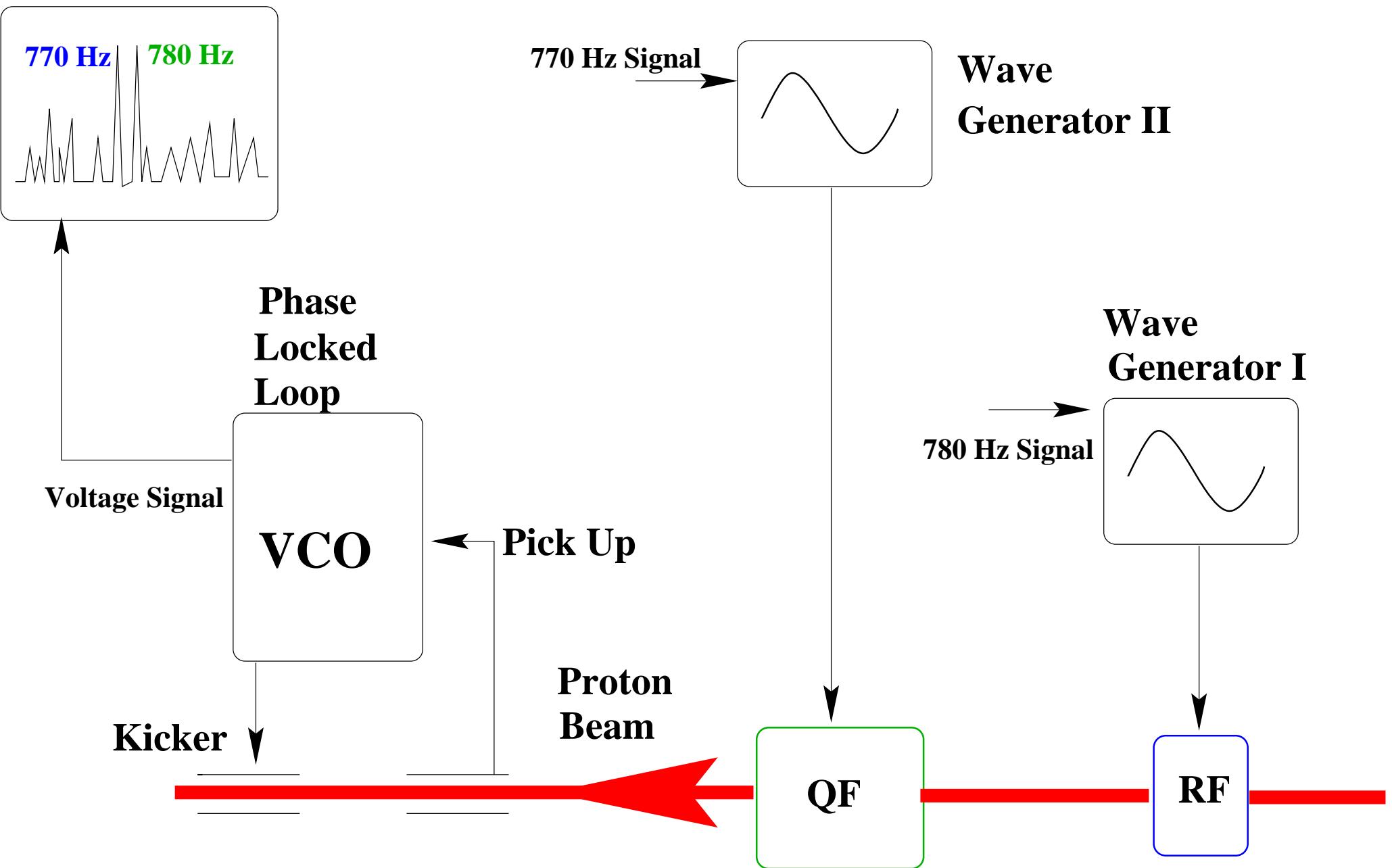
- \longrightarrow energy modulation: $\frac{\Delta E}{E_0} \approx 5 \cdot 10^{-5}$

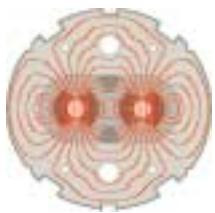
- \longrightarrow extra cavity power: 22.5 kW/cavity at injection
180 kW/cavity at top energy

- \longrightarrow maximum beam intensity limited by RF power

- SPS measurements showed neither particle losses nor emittance growth during the RF phase modulation

Spectrum Analyzer



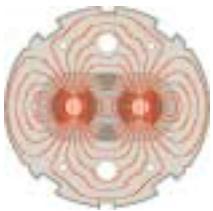


Chromaticity Measurement via RF Phase Modulation

● ***first measurements in the SPS 2.10.2001:***

Oliver Bruning, Wolfgang Hofle, Rhodri Jones, Trevor Linnecar

- no PLL -> measurement with transverse excitations and pickup
- single bunch measurement at 26 GeV $N \approx 4.2 \cdot 10^{10}$
- energy modulation: $\frac{\Delta E}{E_0} \approx 1 \cdot 10^{-4}$
- chromaticity variation: $0.0 < \xi < 13.0$
$$\Delta Q = \xi \cdot \frac{\Delta E}{E_0}$$



Chromaticity Measurement via RF Phase Modulation



measurement goals:

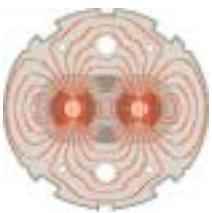
■ demonstrate that RF phase modulation can produce

$$\xrightarrow{\hspace{1cm}} \frac{\Delta E}{E_0} \approx 1 \cdot 10^{-4}$$

■ demonstrate that one can detect resulting signal in transverse plane

■ demonstrate that phase modulation is non-destructive

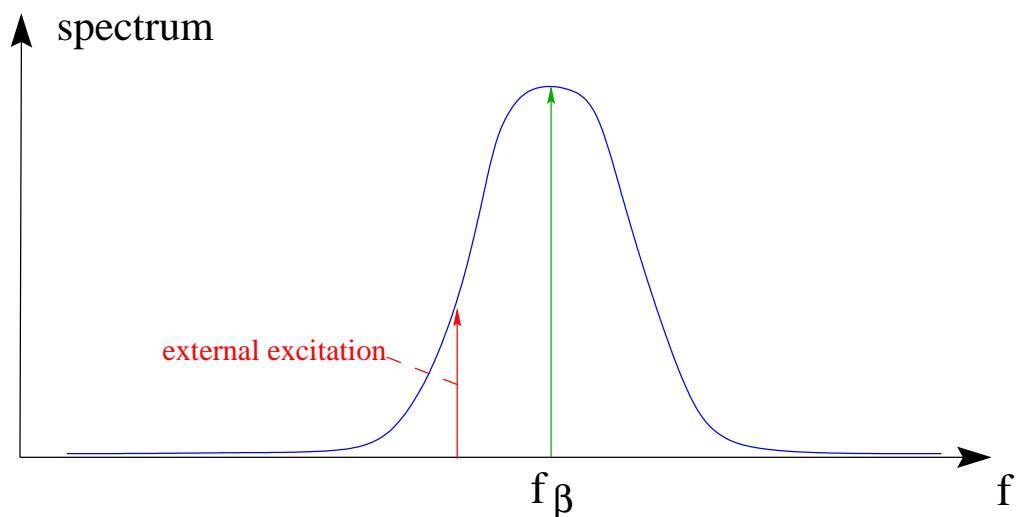
■ demonstrate that the transverse signal is proportional to ξ



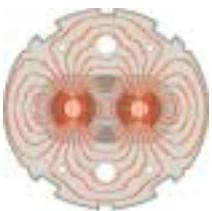
Chromaticity Measurement via RF Phase Modulation

- ***measurement in the vertical plane (no dispersion):***

(Herman Schmickler)



- varying the central beam energy changes the position of the distribution in the spectrum for: $\xi \neq 0$
- modulating the central beam energy shows up in the FFT of the beam response: FFT line proportional to ξ



Chromaticity Measurement via RF Phase Modulation

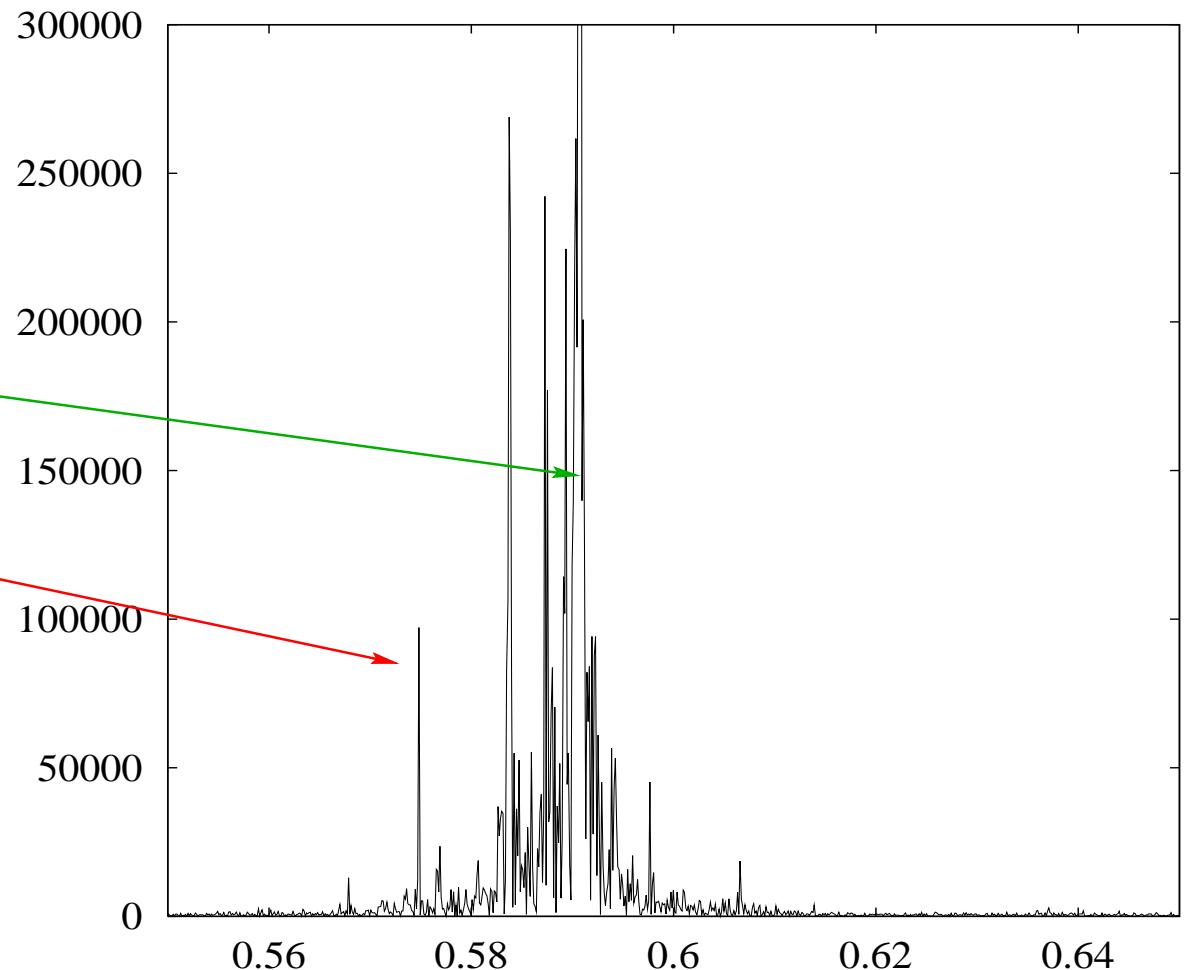
- *typical spectrum:*

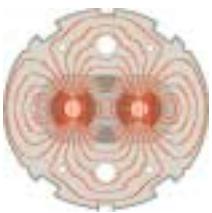
$$Q_v = 0.59$$

$$f_{\text{kicker}} = 17.74 \text{ kHz} \quad (Q = 0.59)$$

$$f_{\text{RF}} = 615 \text{ Hz} \quad (Q = 0.576)$$

$$\xi_v = 13$$





Chromaticity Measurement via RF Phase Modulation

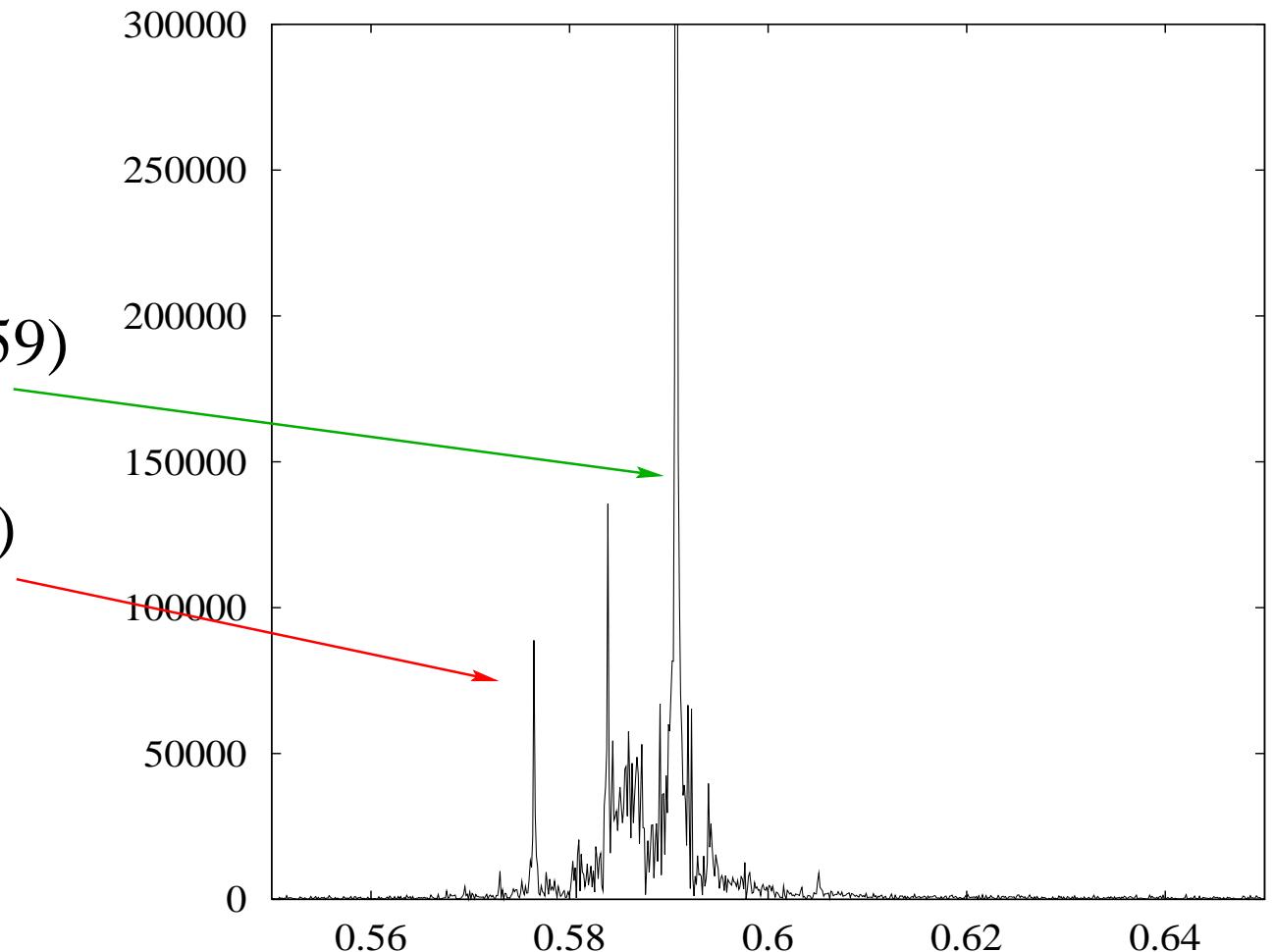
- *typical spectrum:*

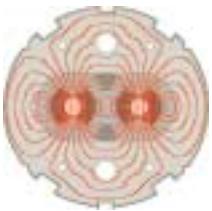
$$Q_v = 0.59$$

$$f_{\text{kicker}} = 17.74 \text{ kHz} \quad (Q = 0.59)$$

$$f_{\text{RF}} = 615 \text{ Hz} \quad (Q = 0.576)$$

$$\xi_v = 10$$





Chromaticity Measurement via RF Phase Modulation

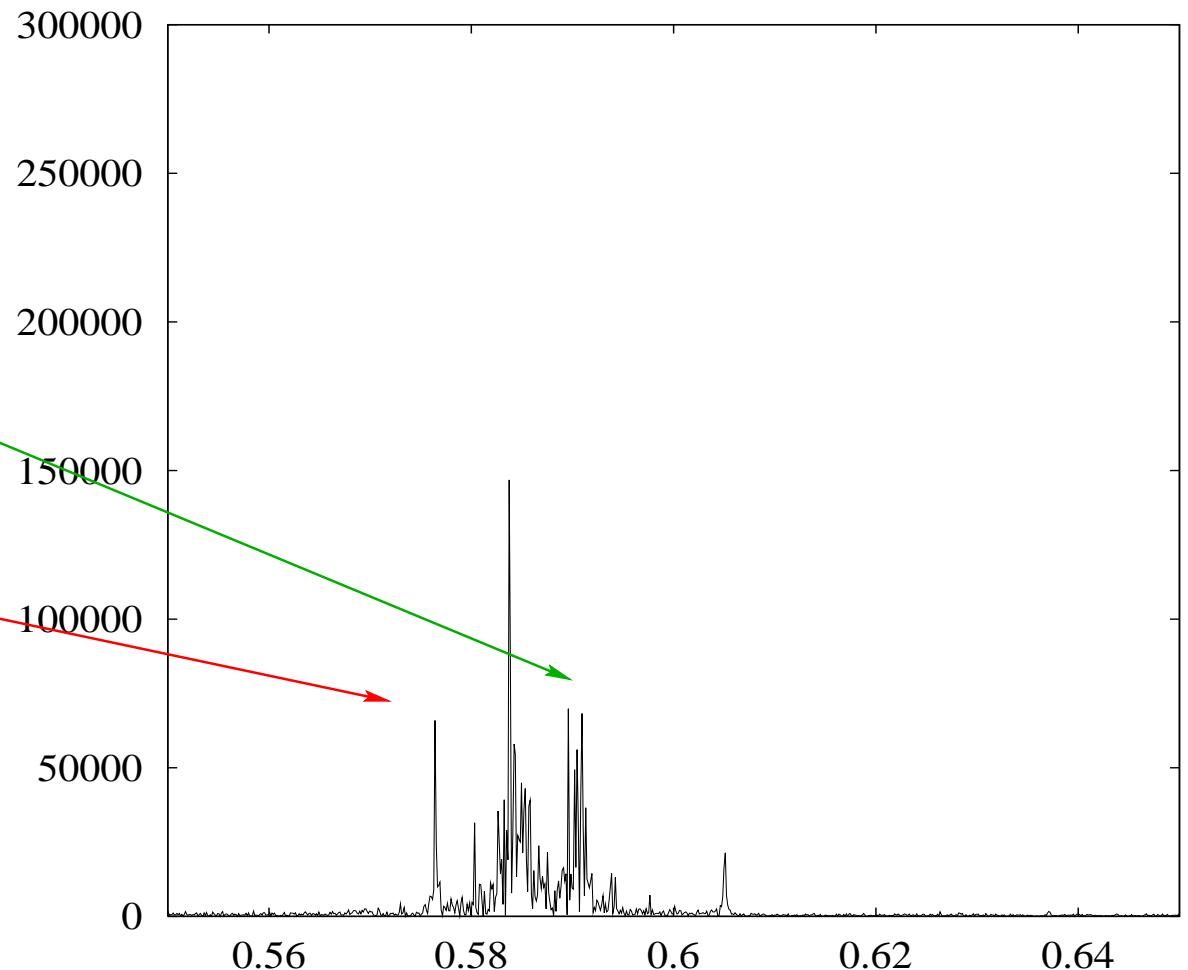
- *typical spectrum:*

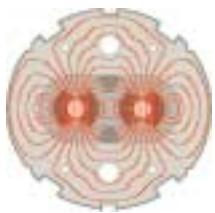
$$Q_v = 0.59$$

$$f_{\text{kicker}} = 17.74 \text{ kHz} \quad (Q = 0.59)$$

$$f_{\text{RF}} = 615 \text{ Hz} \quad (Q = 0.576)$$

$$\xi_v = 7.5$$





Chromaticity Measurement via RF Phase Modulation

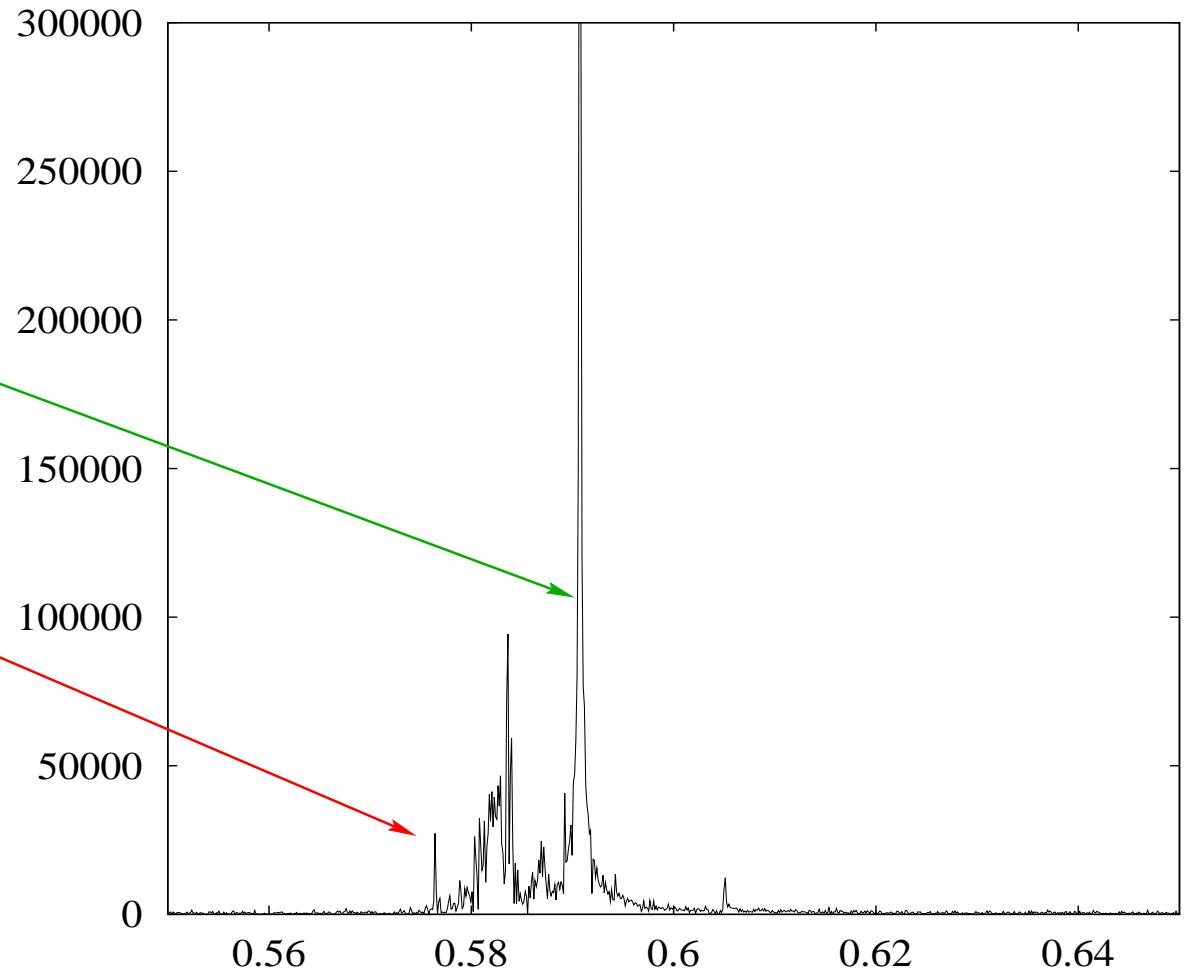
- *typical spectrum:*

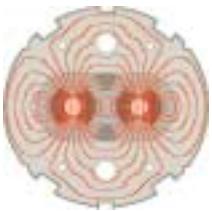
$$Q_v = 0.59$$

$$f_{\text{kicker}} = 17.74 \text{ kHz} \quad (Q = 0.59)$$

$$f_{\text{RF}} = 615 \text{ Hz} \quad (Q = 0.576)$$

$$\xi_v = 5$$





Chromaticity Measurement via RF Phase Modulation

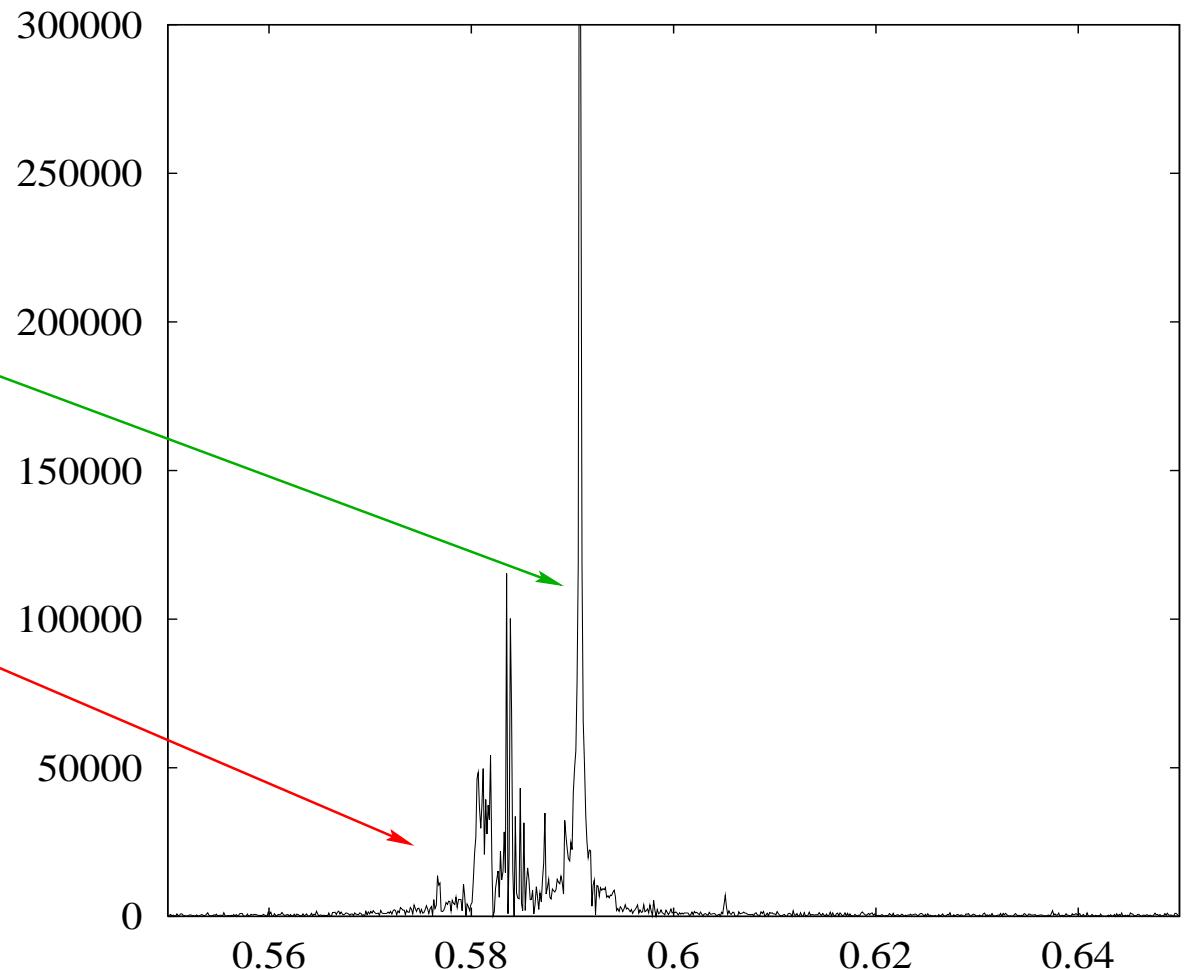
- *typical spectrum:*

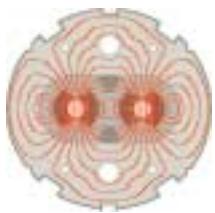
$$Q_v = 0.59$$

$$f_{\text{kicker}} = 17.74 \text{Hz} \quad (Q = 0.59)$$

$$f_{\text{RF}} = 615 \text{Hz} \quad (Q = 0.576)$$

$$\xi_v = 2.5$$





Chromaticity Measurement via RF Phase Modulation

- **chromaticity scan:**

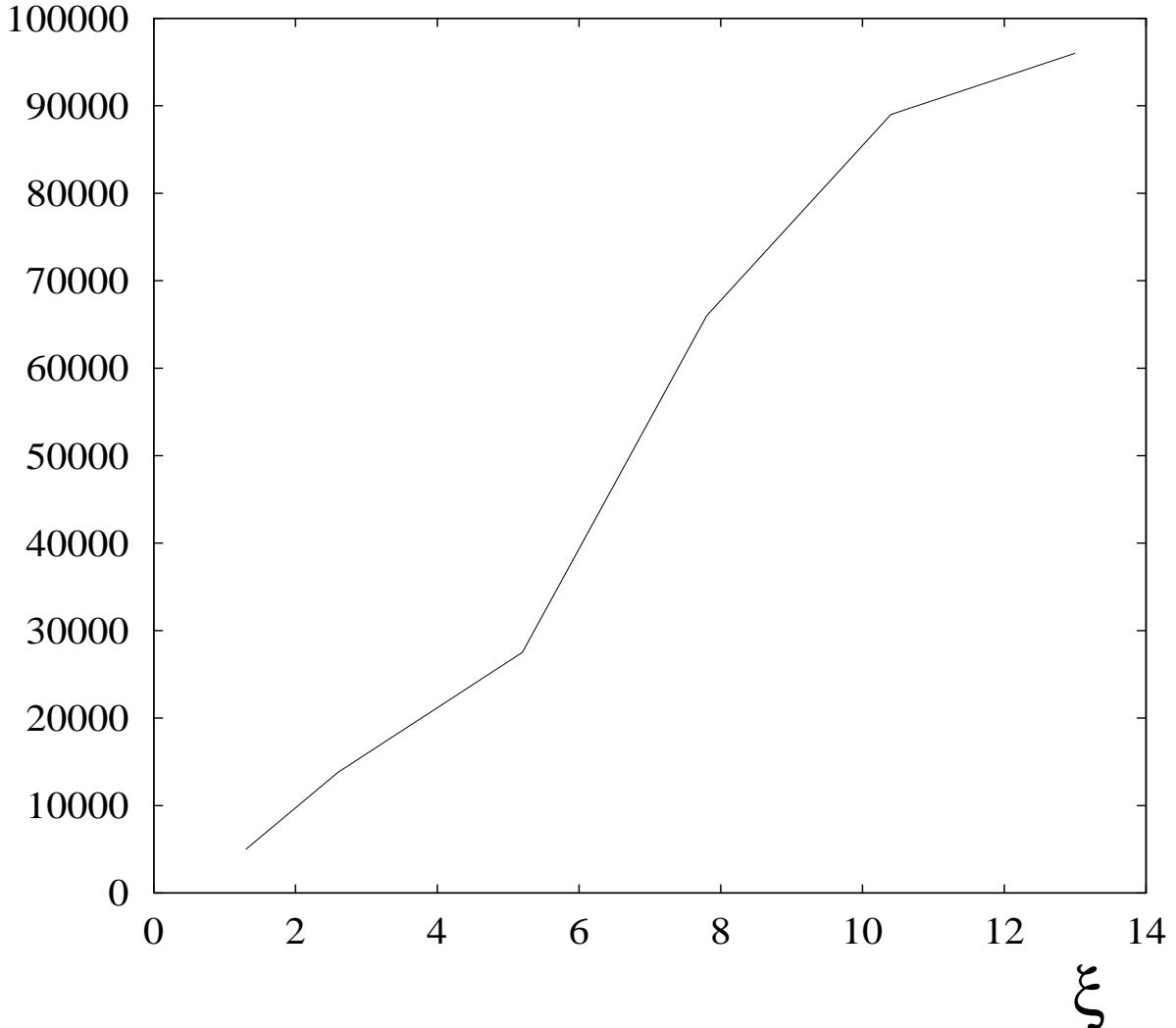
$Q_v = 0.59$

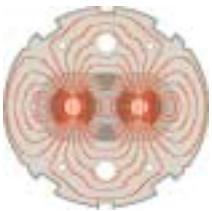
$f_{\text{kicker}} = 17.74 \text{ kHz}$

$f_{\text{RF}} = 615 \text{ Hz} (Q = 0.576)$

$\xi_v = 2.5 \leftrightarrow 13$

amplitude of RF line





Chromaticity Measurement via RF Phase Modulation

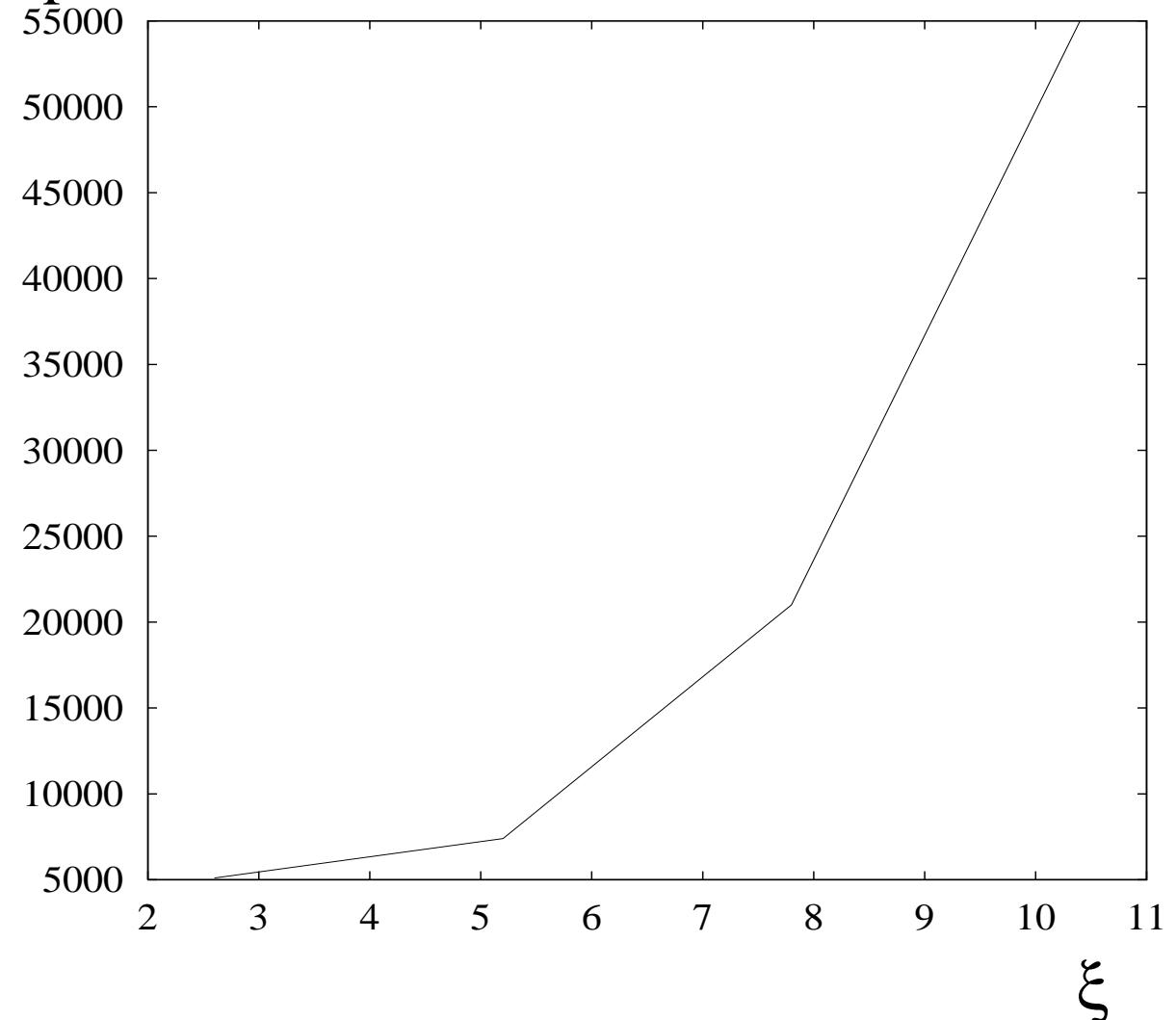
- **chromaticity scan:** amplitude of RF line

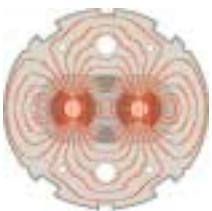
$$Q_v = 0.59$$

$$f_{\text{kicker}} = 17.74 \text{ kHz}$$

$$f_{\text{RF}} = 780 \text{ Hz} (Q = 0.584)$$

$$\xi_v = 2.5 \leftrightarrow 13$$





Chromaticity Measurement via RF Phase Modulation

- **chromaticity scan:**

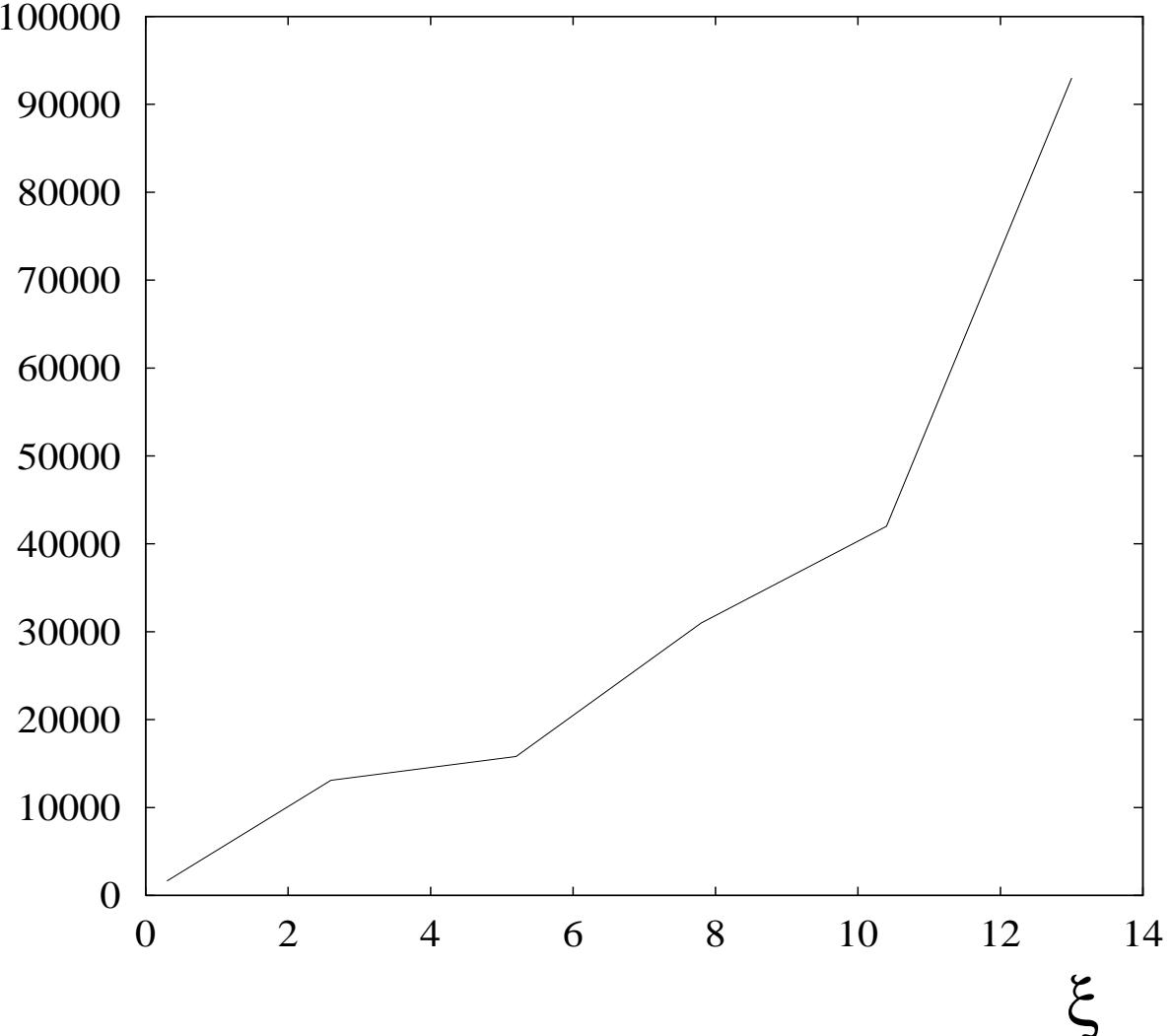
$$Q_v = 0.59$$

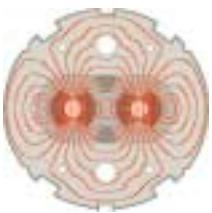
$$f_{\text{kicker}} = 18.58 \text{ kHz} \quad (Q = 0.57)$$

$$f_{\text{RF}} = 780 \text{ Hz} \quad (Q = 0.584)$$

$$\xi_v = 2.5 \leftrightarrow 13$$

amplitude of RF line





Chromaticity Measurement via RF Phase Modulation

- *typical spectrum:*

$$Q_v = 0.59$$

$$f_{\text{kicker}} = 18.62 \text{Hz} \quad (Q = 0.57)$$

$$f_{\text{RF}} = 615 \text{Hz} \quad (Q = 0.576)$$

$$\xi_v = 7.5$$

